This Page Is Inserted by IFW Operations
and is not a part of the Official Record

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images may include (but are not limited to):

- BLACK BORDERS

- TEXT CUT OFF AT TOP, BOTTOM OR SIDES

- FADED TEXT

- ILLEGIBLE TEXT

- SKEWED/SLANTED IMAGES

- COLORED PHOTOS

- BLACK OR VERY BLACK AND WHITE DARK PHOTOS

- GRAY SCALE DOCUMENTS

IMAGES ARE BEST AVAILABLE COPY.

As rescanning documents *will not* correct images,
please do not report the images to the
Image Problem Mailbox.

PCT

(51) International Patent Classification 6 :		(11) International Publication Number:	WO 97/12210
G01F 1/66, 1/72, A61B 5/027, 5/0285	A1	(43) International Publication Date:	3 April 1997 (03.04.97)

(21) International Application Number: PCT/SG95/00012

(22) International Filing Date: 14 December 1995 (14.12.95)

(30) Priority Data:
9501443-7   29 September 1995 (29.09.95)   SG

(71)(72) Applicant and Inventor: TJIN, Swee, Chuan [SG/SG];
Block 835, 83 Woodlands Street #08-129, Singapore 730853
(SG).

(74) Agent: HELEN YEO & PARTNERS; 11 Collyer Quay #12-01,
The Arcade, Singapore 049317 (SG).

(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH,
CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE,
KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN,
MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK,
TJ, TM, TT, UA, UG, US, UZ, VN, ARIPO patent (KE,
LS, MW, SD, SZ, UG), European patent (AT, BE, CH, DE,
DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI
patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE,
SN, TD, TG).

Published
With international search report.

(54) Title: FIBER OPTIC CATHETER FOR ACCURATE FLOW MEASUREMENTS
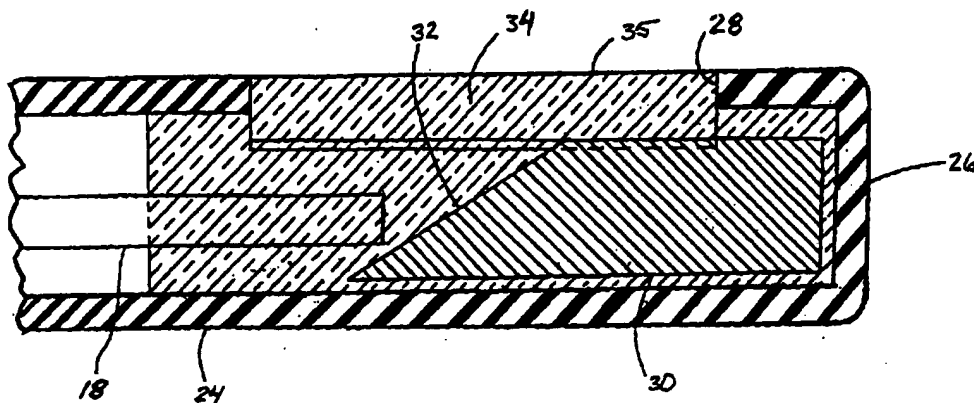
(57) Abstract

An improved fibre optic sensor for remote flow measurements is disclosed. The sensor consists of two optical fibres (16, 18) placed parallel to each other with a reflective surface (32) (flat or concave) at the end. The fibres and the reflective surface are encased in a flexible tube (24) with an opening (28) in the side of the tube to allow light to be reflected through the opening into a measurement volume of the flow. The cavity created by this opening in the flexible tube is preferably filled with optical cement (34). This surface is polished so that it is flushed with the surface. Light is transmitted to the measurement volume from one of the optical fibres (Transmitting fibre) where it is scattered by scattering particles within this measurement volume. Part of backscatter light is collected by the other fibre (receiving fibre) and the backscatter signal is compared with the transmission signal to determine a Doppler shift.

5   FIBRE OPTIC CATHETER FOR ACCURATE FLOW
                                    MEASUREMENTS

                          BACKGROUND OF THE INVENTION

       1.   FIELD OF THE INVENTION
                   The present invention relates to an
10   improved fibre optic probe, or sensor, for remote
       flow measurements. In particular, this sensor is
       designed for accurate flow measurements of fluids
       flowing in remote vessels, such as blood flow
       within arteries or veins or flows within pipes.

15   2.   BACKGROUND INFORMATION
                   Fibre-optic anemometry is employed in
       velocimetry to measure flow rates, velocity
       gradients, and turbulence at remote points which
       are otherwise inaccessible. For example, by
20   measuring the velocity of blood flow in an artery
       before, during, and after an angioplasty
       procedure, the success of the procedure can be
       ascertained. Laser light is transmitted, via
       optic fibres, into the flow where it is scattered.
25   A portion of the scattered light is collected and
       transmitted, also via optic fibres, to an
       anemometer for analysis. By analyzing the Doppler
       shift between the transmitted light and the
       collected scattered light, the velocity of fluid
30   flow can be ascertained.
                   Optical fibres were first used in laser
       Doppler anemometers for the measurement of
       localized blood flow velocities by T. Tanaka and
       G.B. Benedek and described in an article entitled
35   Measurement of the Velocity of Blood Flow (In
       Vivo) Using Fibre Optic Catheter and Optical
       Mixing Spectroscopy, 14 Applied Optics 189-196
       (1975). In their system they used a 500μm core

5   diameter monofibre to deliver the laser beam into
    the femoral vein of a rabbit. The immersed distal
    end of the fibre was cut and polished at 30°
    relative to the fibre axis in an attempt to
    minimize flow disturbance caused by the mere
10 presence of the fibre in the blood stream. A
    laser beam was projected out through the fibre
    wall, opposite the cut end surface, into the flow
    by total internal reflection at the angled
    polished distal end of the fibre. Light scattered
15 by the erythrocytes at the fibre tip was collected
    by the same fibre and mixed with the reference
    beam on the surface of a photomultiplier tube.
    Analysis of the resultant signal was done on an
    18-channel digital autocorrelator.
20   The sensor of the Tanaka-Benedek system
    suffers from a number of disadvantages.
    Projection of light out of the side of the fibre
    necessitates that the fibre be stripped to its
    core, thus leaving the brittle and fragile fibre
25 core exposed and unprotected. Cutting and
    polishing the distal end of the fibre is a
    difficult operation to perform, thus causing
    manufacturing complications. Finally, due to the
    small radius of curvature of the exposed fibre,
30 the curved outer surface of the fibre could cause
    most of the light scattered back to the fibre to
    be lost at the fibre-fluid interface, especially
    if there are irregularities on the surface.
            R.B. Dyott, in an article entitled The
35 Fibre-Optic Doppler Anemometer, 2 Microwaves,
    Optics and Acoustics 13-18 (1978), discusses
    making flow measurements using a single optic
    fibre laser Doppler anemometer with the fibre
    normally terminated. He reported that the region
40 in which light is back-scattered into the fibre
    extends only to a few tens of the core diameter in

5   front of the fibre tip. As demonstrated in FIG.
       10, the flow in this region, indicated at 70, is
       perturbed by the presence of the distal end of the
       fibre which could seriously affect the accuracy of
       any measurements of flow velocity. The Dyott
10   system is well suited, however, to measurements in
       situations where the medium is stationary and the
       particles are moving.
             For flow measurements, G.A. Holloway,
       Jr. and D.W. Watkins modified the Tanaka-Benedek
15   system by using separate fibres for delivering the
       laser beam and receiving the scattered light as
       described in Laser Doppler Measurement of
       Cutaneous Blood Flow, 69 J. Investigative
       Dermatology 306-309 (1977). They applied such a
20   modified system for non-invasive measurement of
       cutaneous microcirculation. The disadvantages
       described above regarding the single fibre Tanaka-
       Benedek system are exacerbated by the inclusion of
       a second fibre.
25   For invasive flow measurements, D.
       Kilpatrick adapted Dyott's system by modifying the
       analyzing components and described the adapted
       system in Laser Fibre Optic Doppler Anemometry in
       the Measurement of Blood Velocities In Vivo,
30   Computers in Cardiology, IEEE, 467-470 (1980). By
       using this system, he showed that, despite flow
       perturbation caused by the presence of the fibre,
       the system could still be used to measure blood
       flow velocities both in vitro and in vivo. With
35   the fibre positioned parallel to fluid flow he
       obtained a broad spectrum, declining monotonically
       with width, that is proportional to the flow
       velocity. The maximum Doppler shift frequency was
       taken as representative of the flow velocity and
40   this agreed with the calculated theoretical value
       of $4.2Mhz/ms^{-1}$ (i.e. the maximum shift frequency is

5 absolutely calibrated). A linear relationship was obtained between the maximum shift frequencies and the flow velocities for flows of up to 1.5ms^{-1} in the forward direction (advancing towards the fibre tip) but only 20cms^{-1} for flows in the reverse

10 direction (moving away from the fibre distal end tip).

    Concurrently with the work of Kilpatrick described above, M. Imamura, F. Kajiya, and N. Hoki independently developed a similar system, but

15 with an added advantage of being able to measure directional flow, as reported in Blood Velocity Measurement By Laser Doppler Velocimetry With Optical Fibre, Proc. 12th Int. Conf. Med. and Biol. Eng. 35 (1979). They achieved this by using

20 a Bragg cell (acousto-optic modulator) to shift the reference signal by 40MHz. In vivo flow measurements in blood were made via the fibre's distal end and with the whole fibre oriented at a 60° angle to the flow (see FIG. 11), and a broad

25 rectangular spectrum was obtained. A linear relationship was again found between the maximum shift frequencies and flow velocities as in the Kilpatrick adaptation of the Dyott system.

    It is interesting to note the absolutely

30 calibrated linear relationship between the maximum Doppler shift frequency and flow velocity obtained for the Kilpatrick and Imamura-Kajiya-Hoki systems described above. This relationship implies that single fibre systems measure the free stream flow

35 velocity (i.e, velocity outside the perturbed region), but only within certain velocity limits. Outside these limits, however, the system will either have to be modified or improved to allow an accurate measurement of flow velocity. The broad

40 spectrum observed by both systems was assumed to be due to multiple frequency shifts from the

5   particles of varying velocity in the perturbed
       region at the tip of the fibre.

               The slight difference in spectral shape
       reported by the Kilpatrick and the Imamura-Kajiya-
       Hoki studies is due to the area of turbulence at
10   the measurement region adjacent the fibres' distal
       end, and this has been theoretically addressed by
       M.D. Stern in Laser Doppler Velocimetry in Blood
       and Multiply Scattering Fluids: Theory, 24 Applied
       Optics 1968-1986 (1985). The difference was
15   attributed to different thicknesses of the
       boundary layer at the distal end tip of the fibre,
       with Kilpatrick's system having a thicker layer.
       To overcome the effect of the boundary layer for
       obtaining accurate flow measurements, it is
20   necessary to project the probe volume (i.e., the
       volume in which flow measurements are made) away
       from or beyond the boundary layer and into the
       laminar flow region. To do this Stern suggested
       use of two fibres, with one fibre delivering the
25   incident light and the other collecting the
       scattered light. The sensor proposed by Stern,
       however, projected the probe volume from the blunt
       ends of the fibres.

               A two fibre laser Doppler anemometer
30   with the fibres oriented at 60° to the direction
       of flow was developed, tested, and reported by Y.
       Ogasawara, O. Hiramatsu, K. Mito, and others in A
       New Laser Doppler Velocimeter With a Dual Fibre
       Pickup For Disturbed Flow Velocity Measurement,
35   Circulation, 76, Suppl. 4, 328 (1987) and by F.
       Kajiya, O. Hiramatsu, Y. Ogasawara, and others in
       Dual-Fibre Laser Doppler Velocimeter and its
       Application to the Measurements of Coronary Blood
       Velocity, 25 Biorheology 227-235 (1988). In both
40   systems, two step-index fibres with a core
       diameter of 50μm and a cladding diameter of 62.5μm

5   were used. The scattered light collected by the
     receiving fibre was mixed with the reference beam
     and detected using an avalanche photodiode. The
     spectrum analyzer showed a narrow spectrum (as
     compared with the single fibre system) with a peak
10   value that varied with flow velocity. The
     separation between the cores of the two fibres in
     these systems was 12.5μm.

          By varying the core separation and using
     different fibre combinations, S.C. Tjin, D.
15   Kilpatrick, O. Hiramatsu, Y. Ogasawara, and F.A.
     Kajiya obtained better linearity between the
     Doppler frequencies and flow velocities as the
     core separation was increased with their system
     and findings described in A Dual-Fibre Laser
20   Doppler Anemometer for in Vitro Measurements,
     Proc. 13th Aust. Conf. Optical Fibre Technology,
     245-248 (1988). This improved linearity, however,
     was obtained at the expense of a decreased signal-
     to-noise ratio, and the probe volume was still
25   projected from the distal end of the fibre.
          However, with a fibre probe placed
     parallel to the flow, S.C. Tjin, D. Kilpatrick,
     and P.R. Johnston found that a two-fibre probe
     with the fibre tips normally terminated is
30   inadequate for accurate flow measurements,
     especially for flows moving away from the fibre
     tips, as described in Evaluation of the Two-Fibre
     Laser Doppler Anemometer for In Vivo Blood Flow
     Measurements, Experimental and Flow Simulation
35   Results, 34 Optical Engineering, 460-469 (1995).
     This is because the flow at the fibre distal end
     tips is perturbed, and the region of perturbation
     extends away from the fibre tips with increasing
     flow velocity. For flow towards the fibre tips,
40   the region of flow perturbation decreases towards
     the fibre tips with increasing flow velocity.

5   These changes in the region of flow perturbation
        with flow velocities and the direction of flow
        give rise to a non-linear calibration between the
        Doppler frequency and the flow velocity. This
        limits the usefulness of the system for in vivo
10   flow measurements because, in most practical
        systems, the fibre optic probe must be placed
        parallel to the flow.
                A two fibre sensor adapted to project a
        probe volume to the side of the catheter wall by
15   means of reflective surfaces was proposed by S.C.
        Tjin in Fibre Optic Laser Doppler Anemometry,
        Ph.D. Thesis, University of Tasmania, 1991,
        available at the University of Tasmania. Such a
        sensor was, however, never constructed. In the
20   proposed embodiment of the sensor, two fibres are
        embedded in the wall of a larger catheter.
        Proximate each fibre distal end tip, a separate
        opening is formed in the catheter sidewall. An
        angled reflective surface is positioned in the
25   opening axially opposite the fibre distal end tip
        to reflect light from the fibre radially outwardly
        through the opening directly into the flow, which
        is parallel to the fibre axes. This proposed
        embodiment, if built, would have had a number of
30   disadvantages. The uncovered openings at the
        reflective surfaces would themselves cause
        turbulence and would also provide a place for
        blood clots to form or collect. To minimize the
        size of the openings, and thus the amount of
35   turbulence caused thereby, it was proposed that
        two small, circumferentially spaced apart openings
        be provided in the catheter wall rather than a
        single large opening and single reflective surface
        that would be able to accommodate both fibres.
40   Polishing, mounting, and aligning dual reflective
        surfaces, however, would introduce manufacturing

-7-

5   complexity and alignment problems to developing a
       suitable probe volume and would add cost to the
       manufacture of the sensor. Also, the embodiment,
       as proposed, included no provision for focusing
       the transmitted and received light beams to
10   minimize the width of the Doppler spectrum and
       maximize the signal-to-noise ratio.

                    SUMMARY OF THE INVENTION
               An object of the present invention is to
       provide a two-fibre probe that avoids the problem
15   of non-linear calibration between the Doppler
       frequency and the flow velocity due to flow
       perturbation caused by the sensor. In addition,
       an object of the present invention is to provide a
       sensor that projects a probe volume to the side of
20   the sensor to avoid turbulence caused by the
       sensor, the sensor being relatively simple to
       manufacture and eliminating structural features
       that would themselves cause turbulence or collect
       blood clots.
25   Consistent with this object, a new two
       fibre optic measuring probe has been designed,
       which can be incorporated into any existing
       catheter, to provide accurate fluid flow
       measurements, not axially via the distal end of
30   the fibre, but radially with respect to the axes
       of the fibres. The measuring probe comprises two
       or more optical fibres placed alongside each other
       within a flexible tube. Light is transmitted into
       the blood stream through one of the fibres, termed
35   the transmitting fibre. A reflective surface,
       located axially within the flexible tube relative
       to the terminal ends of the fibres, is polished or
       otherwise formed with the reflective surface
       oriented at an angle with respect to the axes of
40   the fibres. The reflective angled surface will

5   reflect the light from the transmitting fibre,
     through an optically transparent window in the
     sidewall of the tube. Thus, light is reflected
     into the blood stream alongside the catheter where
     blood flow is not usually perturbed by the
10   presence of the catheter and is more likely to be
     laminar.

             This radially projected light is
     scattered by scattering particles within the probe
     volume, thus developing backscatter light with
15   part of the backscatter light being collected by
     the other fibre, termed the receiving fibre.

             A cavity surrounding the ends of the
     optical fibres and the reflective surface is
     filled with an appropriate optical cement to both
20   fix the optical fibres and the reflective surface
     in place and to provide an optical window for the
     sensor that is flush with the outer surface of the
     catheter tube. This minimizes flow perturbations
     along the side of the sensor and also prevents
25   blood from entering a cavity where it may
     contribute to the formation of undesirable clots.

             Variations on this design include a
     variety of shapes for the fibre tips, including
     tips that are normal to the fibre axes or tips
30   that are concave or convex. Concave and convex
     fibre tips serve the additional purpose of being
     able to effectively focus the incident and
     received beams at more specific locations to
     increase the intensity of the incident beam and to
35   narrow the field of view of the receiving beam to
     effectively shrink the size of the probe volume
     and thus improve the signal to noise ratio and the
     Doppler spectrum

             Another variation of the measuring probe
40   of the present invention includes a reflective
     surface that is concave instead of flat. This

5   complexity and alignment problems to developing a
        suitable probe volume and would add cost to the
        manufacture of the sensor. Also, the embodiment,
        as proposed, included no provision for focusing
        the transmitted and received light beams to
10   minimize the width of the Doppler spectrum and
        maximize the signal-to-noise ratio.

                    SUMMARY OF THE INVENTION
                    An object of the present invention is to
        provide a two-fibre probe that avoids the problem
15   of non-linear calibration between the Doppler
        frequency and the flow velocity due to flow
        perturbation caused by the sensor. In addition,
        an object of the present invention is to provide a
        sensor that projects a probe volume to the side of
20   the sensor to avoid turbulence caused by the
        sensor, the sensor being relatively simple to
        manufacture and eliminating structural features
        that would themselves cause turbulence or collect
        blood clots.
25   Consistent with this object, a new two
        fibre optic measuring probe has been designed,
        which can be incorporated into any existing
        catheter, to provide accurate fluid flow
        measurements, not axially via the distal end of
30   the fibre, but radially with respect to the axes
        of the fibres. The measuring probe comprises two
        or more optical fibres placed alongside each other
        within a flexible tube. Light is transmitted into
        the blood stream through one of the fibres, termed
35   the transmitting fibre. A reflective surface,
        located axially within the flexible tube relative
        to the terminal ends of the fibres, is polished or
        otherwise formed with the reflective surface
        oriented at an angle with respect to the axes of
40   the fibres. The reflective angled surface will

                            -8-

5   reflect the light from the transmitting fibre,
     through an optically transparent window in the
     sidewall of the tube. Thus, light is reflected
     into the blood stream alongside the catheter where
     blood flow is not usually perturbed by the
10   presence of the catheter and is more likely to be
     laminar.

          This radially projected light is
     scattered by scattering particles within the probe
     volume, thus developing backscatter light with
15   part of the backscatter light being collected by
     the other fibre, termed the receiving fibre.

          A cavity surrounding the ends of the
     optical fibres and the reflective surface is
     filled with an appropriate optical cement to both
20   fix the optical fibres and the reflective surface
     in place and to provide an optical window for the
     sensor that is flush with the outer surface of the
     catheter tube. This minimizes flow perturbations
     along the side of the sensor and also prevents
25   blood from entering a cavity where it may
     contribute to the formation of undesirable clots.

          Variations on this design include a
     variety of shapes for the fibre tips, including
     tips that are normal to the fibre axes or tips
30   that are concave or convex. Concave and convex
     fibre tips serve the additional purpose of being
     able to effectively focus the incident and
     received beams at more specific locations to
     increase the intensity of the incident beam and to
35   narrow the field of view of the receiving beam to
     effectively shrink the size of the probe volume
     and thus improve the signal to noise ratio and the
     Doppler spectrum

          Another variation of the measuring probe
40   of the present invention includes a reflective
     surface that is concave instead of flat. This

5   concave surface also helps focus the beam from the
     transmission fibre to a point above the surface of
     the optical cement surface. Part of the light
     scattered by scattering particles in this region
     is collected by the receiving fibre via the
10   concave reflecting surface. A concave reflective
     surface can be combined with fibres having concave
     or convex tips.

            Other objects, features and
     characteristics of the present invention will
15   become apparent upon consideration of the
     following description with reference to the
     accompanying drawings, and in the appended claims,
     all of which form a part of the specification, and
     wherein reference numerals designate corresponding
20   components of the figures.

                BRIEF DESCRIPTION OF THE DRAWINGS
            FIG. 1 shows a conventional catheter
     incorporating an improved measuring probe, or
     sensor tip, according to the present invention;
25   FIG. 2 is an enlarged view of the sensor
     tip of the present invention from above the
     reflective surface;
            FIG. 3 is a cross-sectional view of the
     sensor tip of the present invention along the line
30   III-III in FIG. 2;
            FIG. 4 is an enlarged view of a second
     embodiment of the sensor tip according to the
     present invention from above the reflective
     surface;
35   FIG. 5 is a cross-sectional view of the
     second embodiment of the sensor tip of the present
     invention along the line V-V in FIG. 4;
            FIG. 6 is a cross-sectional view of the
     of the sensor tip of the present invention along
40   the line VI-VI in FIG. 2;

                          -10-

FIG. 7 is a cross-sectional view of the sensor tip of the present invention along the line VII-VII in FIG. 4;

FIG. 8A is a cross sectional view of the sensor of the present invention depicting a third embodiment thereof;

FIG. 8B is a cross sectional view of the sensor of the present invention depicting a fourth embodiment thereof;

FIG. 9A is a cross sectional view of the sensor of the present invention depicting a fifth embodiment thereof;

FIG. 9B is a cross sectional view of the sensor of the present invention depicting a sixth embodiment thereof;

FIG. 10 shows flow perturbation occurring at the blunt end of a prior art sensor tip; and

FIG. 11 shows the flow perturbation occurring at the end of a prior art sensor tip oriented at 60° to the flow.

DETAILED DESCRIPTION OF THE INVENTION

A fibre optic catheter 10 having a measuring sensor 14 according to the present invention is shown in FIG. 1. The catheter 10 includes first and second optic fibres 16, 18 enclosed within a flexible tube 24. The fibres are conventional optical fibres and can, for example, be comprised of glass or plastic. Glass fibres are preferred because of their superior light transmission qualities. The flexible tube is preferably a medical grade tubing, such as heparin (an anticoagulant) coated latex, which is conventionally used in a variety of in vivo applications.

5   A sensor tip, or region, 14 is located
adjacent, but proximally of, a distal end of the
catheter 10, or at any desired location
therealong. Conventional connectors 20, 22 are
fixed to the proximal ends of the optic fibres 16,
10   18, respectively. The connectors 20, 22 connect
the catheter 10 to an anemometer or other suitable
analyzing device. With the exception of the use
of the present invention sensor, the catheter 10,
including the connectors 20, 22, is of
15   conventional construction and design for a two
optic fibre catheter.

The construction of the sensor in the
sensoring region 14 is shown in more detail in
FIGS. 2 and 3. The optic fibres 16, 18 are
20   enclosed by the flexible tube 24 and may terminate
within the tube 24 near, but spaced proximally
from, the distal end 21 of the catheter. It is
presently preferred to use multimode fibres having
a step refractive index profile with a core
25   diameter of 50 μm and a cladding diameter of 125
μm (denoted a 50/125 fibre). A single mode fibre,
having a core diameter of 8 μm and a cladding
diameter of 125 μm (a 8/125 fibre), may also be
used. It is also possible to use a combination of
30   one single mode fibre and one multimode fibre.
For single mode fibres, the preferred core
diameter is dependent on the wavelength of light
to be used.

The distal end 21 of tube 24 is
35   preferably closed by a cap 26, or the like, to
prevent the intrusion of blood into the probe
which might form undesirable clots.

An opening 28 is initially formed in a
sidewall of the tube 24. The terminal ends 17, 19
40   of the optic fibres 16, 18, respectively, are
located within the tube 24 adjacent opening 28.

5   A plug 30 composed of reflective
material is disposed within the tube 24 between
the terminal ends 17, 19 of the optic fibres 16,
18 and the distal end cap 26 of the tube 24. The
plug 30 may be composed of any suitable reflective
10   material, such as copper, stainless steel, silver,
mirrored glass, or the like. Presently a portion
of stainless steel wire having a diameter of 0.2
mm has been employed.

          One end of the plug 30 nearest the
15   terminal ends 17, 19 is ground and polished to
form a finished reflective surface 32 that is
oriented at an angle with respect to the
longitudinal fibre axes of the fibres 16, 18. It
is presently contemplated that the preferred angle
20   of the reflective surface be within the range of
about 25-35° with respect to the longitudinal
fibre axes of the fibres 16, 18, with an angle of
about 30° being preferred.

          Once the fibres and the reflective
25   surface are appropriately aligned, the cavity
within the opening 28 surrounding the optic fibres
16, 18 and the plug 30 is filled with an optical
cement 34. The optical cement may include any
suitable optically transparent material having an
30   initial liquid phase and which hardens after being
poured into the cavity, such as clear polymeric
materials which harden upon exposure to certain
radiation. When set, the optical cement 34 locks
the fibres and the reflective surface 32 together
35   into an integral unit. The cement 34 also
provides a smooth surface over the opening that is
flush with the outer peripheral surface of tube
24. To this end, it is necessary that the optical
cement, forming an optical window 35 when
40   finished, be polished smooth to minimize
turbulence caused by the surface and to prevent

5   blood clots from forming in voids and other
irregularities in the cement. The preferred
optical cement is Norland™ Optical Adhesive 61.
It should be understood, however, that other
optical quality cements can also be employed.

10   In operation, with the catheter inserted
into the blood vessel of a patient or into a flow
within a pipe, a transmission, or incident, beam
of light from a laser, such as, preferably, a
laser diode, such as, for example, the 7350 Series

15   Diffraction Limited Laser Diode, operating in the
wavelength range of 670-680 nm, produced by SDL,
Incorporated of San Jose, California, U.S.A., or
an HeNe laser, exits the terminal end 17 of the
optical fibre 16, here designated as the

20   transmitting, or transmission, fibre. The
wavelength of the light may be any wavelength
within the scattering spectrum of blood, which
ranges from 450-850 nm. Wavelengths within the
red portion of the spectrum, 600-720 nm, are

25   preferred because they provide the most scattering
within blood.

         The incident beam reflects off the
reflecting surface 32 in a direction having a
component normal to the fibre axes out of the

30   optical window 35 formed over the opening 28 in
the tube 24 (see FIG. 6). The light within the
incident beam is reflected into a measurement, or
probe, volume of fluid flow outside of and
alongside the tube 24 in the region near the

35   optical window 35. The reflected light is
scattered by particles flowing within the
measurement volume. A portion of the light is
also scattered back (the backscatter) through the
optical window 35 where it is reflected by the

40   reflecting surface 32 into the terminal end 19 of
the optical fibre 18, here designated as the

5   receiving fibre. The light received by the
     receiving fibre 18 is known as the backscatter
     signal.

          As shown in FIG. 6, the reflected light
     emitted from the transmitting fibre 16 covers a
10   diverging area denoted between lines 36, that can
     be considered as a transmitted acceptance cone.
     The receiving fibre 18 collects light from a
     diverging area, or acceptance cone or field of
     view, denoted between lines 38. The overlap of
15   the transmitted acceptance cone 36 with the field
     of view 38, as shown by the cross-hatched area 40,
     represents the probe volume region wherein the
     incident beam and the backscatter transmission
     overlap. It is in this probe volume where fluid
20   flow is measured.

          The design parameters and the preferred
     values of those parameters will now be described.

          Depending on the angle of the reflective
     surface, the probe volume may be projected out of
25   the optical opening normal to the fluid flow
     (i.e., normal to the fibre axes) or forwardly or
     rearwardly with respect to the fibre tips. To
     obtain the largest Doppler shift, however, it is
     preferred that the probe volume be projected as
30   far forwardly or rearwardly as possible. If the
     probe volume is projected normally to the fibre
     axes, there is no Doppler shift and the flow
     velocity cannot be ascertained.

          In addition, the height of the probe
35   volume above the wall of the catheter 24 (i.e.,
     the distance the probe volume 40 in FIG. 6 is
     spaced radially from the optic window 35) is also
     critical. The probe volume must be a sufficient
     distance, or at a sufficient projection height,
40   from the catheter so that the probe volume is out
     of the boundary layer of the flow along the

5   sidewall of catheter 24. On the other hand, if
        the probe volume is too far from the catheter
        sidewall, the laser transmission light cannot
        sufficiently penetrate the opaque fluid, such as
        blood. The projection height of the probe volume,
10   thus, depends on a number of factors, including
        the index of refraction of the optical cement and
        the angle of the reflective surface. The greater
        the reflective surface angle, the higher the
        projection height. Projection height also depends
15   on the position of the reflective surface with
        respect to the fibre tips. The closer the
        reflective surface is to the fibre tips, the
        higher the projection height. Finally, the
        projection height depends on the separation
20   between the two fibres. The greater the
        separation, the greater the projection height.

               To ensure that the acceptance cones of
        the transmission fibre and the receiving fibre are
        correctly projected out of the catheter and window
25   35, the two cones should intersect beyond the
        reflective surface. In other words, the two
        cones, between lines 36 and 38, respectively,
        cannot overlap until they are projected into the
        flow as shown in FIG. 6. To avoid overlap of the
30   acceptance cones prior to their exiting optical
        window 35, the fibre core centers must be spaced
        at least 260 μm apart.

               In addition, the reflective surface
        cannot be too far from the fibre tips. The beam
35   angle of the transmission light depends on the
        index of refraction of the optical cement. Using
        the preferred optical cement, Norland™ Optical
        Adhesive 61, which has an index of refraction of
        1.5562, the acceptance cones of two 50/125
40   multimode fibres, whose cores as separated by 260
        μm, will intersect each other at a distance of 290

5   μm from the fibre tips. Therefore, the
       intersection of the fibre axes with the reflective
       surface must be within 290 μm of the fibre tips.
              Although it is preferred that the probe
       volume 40 be projected as far forwardly or
10   rearwardly along the catheter 24 as possible, the
       angle of the reflective surface cannot be so great
       or so small that the reflected transmission light
       does not leave the optical window due to total
       internal reflection. To avoid total internal
15   reflection, the angle of the reflective surface
       must be between 25-65° from the fibre axes, but
       not, preferably, exactly at 45°. Where the angle
       is progressing greater than 45°, the probe volume
       will be progressively projected rearwardly; as the
20   angle becomes less than 45°, the probe volume will
       be progressively projected forwardly. At a 45°
       reflective angle, the probe volume is projected
       normal to the fibre axes.
              A forwardly projected probe volume is
25   preferred. A normally projected probe volume
       would not capture sufficient Doppler shift, as
       noted above. While a rearwardly projected probe
       volume may be blocked by the fibres themselves,
       this could be avoided by moving the fibres away
30   from the reflective surface. This can, however,
       result in the acceptance cones of the fibres
       overlapping before reaching the reflective
       surface.
              As noted previously, the angle of the
35   reflective surface is preferably within the range
       of 25 - 35°, with 30° being preferred. If the
       angle is less than 25° total internal reflection
       will result. If the angle is greater than 35° the
       projection height will be too high.
40   The optical opening must be large enough
       so that the acceptance cones of the fibres are not

5   blocked by the tube wall. For a sensor having
50/125 multimode fibres with a 260 μm separation
between the fibre axes, an optical cement having
an index of refraction of 1.5562, and a reflective
surface with an angle of 30°, the optical opening

10   must have an axial length of at least 600 μm
measured axially from the fibre tips 17, 19 and a
circumferential width of at least 530 μm that is
centered between the optical fibres.

                The plug 30 must have a sufficient

15   diameter such that the acceptance cones of the
fibres are entirely captured by the reflective
surface. The diameter of the catheter primarily
preferred herein is 1.2 mm. For a 1.2 mm diameter
sensor having 50/125 multimode fibres with 135 μm

20   separation therebetween, an optical cement having
an index of refraction of 1.5562, a reflective
surface at an angle of 30°, and with the fibre
axes intersecting the reflective surface at a
distance of 108.25 μm from the fibre tips, the

25   outer diameter of the plug must be at least 204
μm.

                For a sensor employing two 8/125 single
mode fibres, the design parameters are summarized
below:

30 Refractive index of optical cement -	1.5562
Recommended reflective angle -	27°
Minimum plug diameter -	150 μm
Minimum optical opening length - for a 1.2 mm diameter sensor.	400 μm

35   It must be noted that the above preferred
parameters have been developed for prototype
sensors having flat reflective surfaces and
normally positioned fibre tips. Any or all of the
parameter values may differ in a preferred

40   commercial embodiment from those cited above. In

-18-

5   addition, it is important to understand that all
       of the parameters are directly interdependent and
       that variation of any one of the preferred values
       would necessarily change the remaining values.
                    In manufacturing the sensor of the
10   present invention, the fibres are inserted into
       the tube with the plug on which the reflective
       surface is polished. Incident light transmitted
       through the transmission fibre and a received
       light signal are both monitored. The relative
15   orientation of the fibres with respect to the
       protective surface is adjusted until the signal to
       noise ratio is maximized. The optical cement is
       then added to fix the relative positions of the
       fibres and the reflective surface.
20   The sensor of the present invention has
       been described thus far as having a single optical
       opening and window and a single reflective surface
       whereby the single window and reflective surface
       are associated with both fibres and each,
25   respectively, transmits and reflects both the
       incidence signal and the backscatter signal. The
       sensor of the present invention could, however,
       include two or more reflective surfaces axially
       disposed with respect to associated fibre tips in
30   a corresponding number of optical openings having
       associated optical windows. In this embodiment,
       it is contemplated that the incidence beam,
       emitted from a transmitting fibre, is reflected by
       its associated reflective surface out its
35   associated optical window. Similarly, the
       backscatter signal passes through an optical
       window and is reflected by a reflective surface
       associated with a receiving fibre.
                    The sensor of the present invention has
40   also be described as having a single transmitting
       fibre and a single receiving fibre. It is

5   presently contemplated, however, that the sensor
       of the present invention could include two or more
       transmitting fibres and/or two or more receiving
       fibres, at least one optic transmitting path and
       at least one optic receiving path being required.
10   It is desirable that the Doppler
       spectrum be as narrow as possible and that the
       signal to noise ratio be as large as possible. To
       maximize the signal to noise ratio from the
       sensor, and to minimize the width of the Doppler
15   spectrum, it is desirable that the probe volume be
       as small as possible and that the transmission
       beam be as concentrated as possible. To that end,
       a sensor with the capability to focus the
       transmission signal and to focus the field of view
20   of the receiving fibre would provide significant
       advantages over sensors without such capabilities.
               An alternate embodiment of the fibre
       optic catheter of the present invention, which
       includes such focusing capability, is shown in
25   FIGS. 4, 5, and 7. The sensor tip 42 of the
       catheter of the alternate embodiment is, in most
       respects, identical to the sensor tip 14 of the
       first embodiment. The reflective surface 46 of
       the plug 44 is not, however, ground flat as in the
30   first embodiment, but is ground with a concave
       shape as shown schematically in FIG. 5. As
       demonstrated in FIG. 7, the concave surface helps
       focus the incident beam 48 from the transmission
       fibre 16 to a smaller region above the surface of
35   the sensor. Furthermore, by virtue of the concave
       reflective surface 46, the region from which light
       is collected by the receiving fibre 18, indicated
       between lines 50, is also focused so as to be
       narrower than without such focusing. This results
40   in a narrower probe volume 52 which causes a
       stronger signal to noise ratio and a narrower

5   Doppler spectrum.

As noted above the index of refraction
of the optical cement presently used is 1.5562.
The index of refraction of the fibre core
typically ranges from about 1.4 - 1.5.

10   Accordingly, the acceptance cone of the
transmission beam is enlarged upon being emitted
from the fibre tip into the optical cement. This
results in an undesired enlargement of the probe
volume and a decrease in the light intensity. If

15   the index of refraction of the optical cement were
less than that index of refraction of the fibre
core, however, the acceptance cone would shrink,
resulting in built-in focusing effect.

As noted above, the shape of the

20   reflective surface can itself be modified to focus
the transmission signal and the field of view of
the receiving fibre. Similarly, the tips of the
fibres may be shaped so as to produce such a
focusing effect.

25   Further embodiments of the sensor of the
present invention are shown in FIGS. 8 and 9. The
sensor of FIG. 8A, has fibre tips 60 that are
convex in shape. Where the index of refraction of
the optical cement 64 is less than the index of

30   refraction of the fibre core, the convex fibre
tips 60 of the sensor of FIG. 8A will result in a
more focused probe volume and thus a stronger
signal to noise ratio and narrower Doppler
spectrum. Conversely, where the index of

35   refraction of the optical cement 64 is greater
than the index of refraction of the fibre core,
the convex fibre tips 60 of the sensor of FIG. 8A
will result in a less focused probe volume.

The sensor of FIG. 8A has a flat

40   reflective surface 32. The sensor of FIG. 8B, has
fibre tips 60 that are convex combined with a

5   concave reflective surface 46 resulting in even
       more focusing of the probe volume.

               The sensor of FIG. 9A, has fibre tips 62
       that are concave. Where the index of refraction
       of the optical cement 66 is greater than the index
10   of refraction of the fibre core, the concave fibre
       tips 62 of sensor of FIG. 9A will result in a more
       focused probe volume and thus a stronger signal to
       noise ratio and narrower Doppler spectrum.
       Conversely, where the index of refraction of the
15   optical cement 66 is less than the index of
       refraction of the fibre core, the concave fibre
       tips 62 of sensor of FIG. 9A will result in a less
       focused probe volume.

               The sensor of FIG. 9A has a flat
20   reflective surface 32. The sensor of FIG. 9B, has
       fibre tips 62 that are concave combined with a
       concave reflective surface 46 resulting in even
       more focusing of the probe volume.

               In analyzing the signals received by the
25   receiving fibre of the two-fibre sensor, the
       backscatter signal is compared to the incident
       signal in a known manner so as to determine the
       Doppler shift of the backscatter signal. As is
       well known in the art, the flow velocity of fluid,
30   such as blood, is directly proportional to Doppler
       shift frequency. The velocity may be represented
       mathematically by the expression:

               $V = K \cdot f_D$

               where,

35   V   =   Blood Flow Velocity;

               K   =   Doppler shift constant to be
                             determined in a known manner;
                             and

               f_D =   the Doppler shift frequency,
40   to also be determined in a
                             known manner.

5   The Doppler shift constant K is
           calculated by the following equation:

                     $K = - \dfrac{2n}{\lambda} \cos \theta$

                     where,

10   n   =   index of refraction of blood $\approx$
                              1.33;

                     θ   =   obtuse angle between direction
                              of flow and the bisection of
                              the transmission cone
15   projected from the optical
                              window; and

                     λ   =   wavelength of the light.

                     While the invention has been described
           in connection with what are presently considered
20   to be the most practical and preferred
           embodiments, it is to be understood that the
           invention is not to be limited to the disclosed
           embodiments, but, on the contrary, it is intended
           to cover various modifications and equivalent
25   arrangements included within the spirit and scope
           of the appended claims.

                     Such modifications, which would be
           included within the scope of the appended claims,
           include, but are not limited to, a fibre optic
30   sensor having two or more transmitting fibres
           and/or two or more receiving fibres and a sensor
           having two or more reflective surfaces axially
           disposed with respect to associated fibre tips in
           a corresponding number of optical openings having
35   associated optical windows.

                     Thus, it is to be understood that
           variations in the particular parameters used in
           defining the improved fibre optic probe can be
           made without departing from the novel aspects of
40   this invention as defined in the claims.

5   WHAT IS CLAIMED IS:

1.   A sensor for remote fluid flow measurements, said sensor comprising:

a flexible tube having an optical opening formed in a sidewall thereof;

10   first and second optical fibres disposed within said tube, said first and second optical fibres each having a longitudinal fibre axis and a terminal end disposed within said tube proximate said optical opening; and

15   a single reflective surface disposed within said tube adjacent said terminal ends of said first and second optical fibres,

wherein said optical opening and a portion of said tube surrounding said terminal
20   ends of said first and second optical fibres and said reflective surface define a cavity, said cavity being filled with an optical cement forming an optical window,

said single reflective surface being
25   oriented such that light emitted from said terminal end of one of said first and second optical fibres is reflected by said single reflective surface in a direction having a component normal to the fibre axes through said
30   optical cement into a measurement volume of the flow located outside and alongside said sensor, the reflected light being scattered within the measurement volume such that a portion of the scattered light that is within a field of view of
35   the other of said first and second optical fibres is scattered back through said optical cement and is reflected by said single reflective surface into said terminal end of the other of said first and second optical fibres.

5   2.   The sensor of claim 1 wherein said
single reflective surface is flat.

        3.   The sensor of claim 1 wherein said
single reflective surface is concave.

        4.   The sensor of claim 1 wherein said
10   single reflective surface is disposed adjacent the
distal end of said tube.

        5.   The sensor of claim 1 wherein said
single reflective surface is composed of stainless
steel.

15   6.   The sensor of claim 2 wherein said
single reflective surface is oriented at an angle
of between 25 and 35 degrees with respect to the
longitudinal fibre axes of said first and second
optical fibres.

20   7.   The sensor of claim 1 wherein said
terminal ends of said first and second optical
fibres are normal with respect to the longitudinal
fibre axes of said first and second optical
fibres.

25   8.   The sensor of claim 1 wherein at least
one of said single reflective surface and said
terminal ends of said first and second optical
fibres is shaped so as to focus the light
reflected into the flow and to focus the field of
30   view of the other of said first and second optical
fibres.

        9.   The sensor of claim 1 wherein said first
and second optical fibres each comprises a core
and a surrounding cladding layer and wherein said

-25-

5   optical cement has an index of refraction that is
       greater than an index of refraction of said cores.

       10.   The sensor of claim 1 wherein said first
       and second optical fibres each comprises a core
       and a surrounding cladding layer and wherein said
10   optical cement has an index of refraction that is
       less than an index of refraction of said cores.

       11.   The sensor of claim 9 wherein said
       terminal ends of said first and second optical
       fibres are concave in shape.

15   12.   The sensor of claim 10 wherein said
       terminal ends of said first and second optical
       fibres are convex in shape.

       13.   The sensor of claim 3 wherein said
       terminal ends of said first and second optical
20   fibres are normal with respect to the fibre axes
       of said first and second optical fibres.

       14.   The sensor of claim 11 wherein said
       single reflective surface is concave.

25   15.   The sensor of claim 12 wherein said
       single reflective surface is concave.

       16.   The sensor of claim 1 wherein at least
       one of said first and second optical fibres is a
       multimode optical fibre.

30   17.   The sensor of claim 1 wherein at least
       one of said first and second optical fibres is a
       single mode optical fibre.

5   18. A sensor for remote fluid flow .
measurements, said sensor comprising:
       a flexible tube having at least one optical
opening formed in a sidewall thereof;
       transmitting and receiving optical fibres
10   disposed within said tube, said transmitting and
receiving optical fibres each having a terminal
end disposed within said tube proximate an
associated opening of said at least one optical
opening; and
15   at least one reflective surface disposed
within said tube adjacent said terminal ends of
said transmitting and receiving optical fibres, a
reflective surface of said at least one reflective
surface being associated with said transmitting
20   optical fibre and a reflective surface of said at
least one reflective surface being associated with
said receiving optical fibre,
       said at least one reflective surface being
oriented such that light emitted from said
25   terminal end of said transmitting optical fibre is
reflected by said reflective surface associated
with said transmitting optical fibre out said
optical opening associated with said transmitting
optical fibre into said fluid and so that back
30   scattered light within a field of view of said
receiving optical fibre reenters said optical
opening associated with said receiving optical
fibre to be reflected by said reflective surface
associated with said receiving optical fibre into
35   said terminal end of said receiving optical fibre,
       said emitted light and said field of view
being focused.

       19. The sensor of claim 18 wherein said
reflective surface associated with said
40   transmitting optical fibre and said reflective

5   surface associated with said receiving optical
       fibre comprise a common reflective surface.

       20.   The sensor of claim 18 wherein said
       optical opening associated with said transmitting
       optical fibre and said optical opening associated
10   with said receiving optical fibre comprise a
       common optical opening.

       21.   The sensor of claim 19 wherein said
       optical opening associated with said transmitting
       optical fibre and said optical opening associated
15   with said receiving optical fibre comprise a
       common optical opening.

       22.   The sensor of claim 18 wherein at least
       a one of said at least one reflective surface and
       said terminal ends of said transmitting and
20   receiving optical fibres are shaped so as to focus
       the emitted light and said field of view.

       23.   The sensor of claim 18 wherein said at
       least one optical opening and a portion of said
       tube surrounding said terminal ends of said
25   transmitting and receiving optical fibres and said
       at least one reflective surface define a cavity,
       said cavity being filled with an optical cement
       forming at least one optical window.

       24.   The sensor of claim 23 wherein said
30   transmitting and receiving optical fibres each
       comprises a core and a surrounding cladding layer
       and wherein said optical cement has an index of
       refraction that is greater than an index of
       refraction of said cores.

5   25.   The sensor of claim 23 wherein said
transmitting and receiving optical fibres each
comprises a core and a surrounding cladding layer
and wherein said optical cement has an index of
refraction that is less than an index of
10   refraction of said cores.

26.   The sensor of claim 24 wherein said
terminal ends of said transmitting and receiving
optical fibres are concave in shape.

27.   The sensor of claim 25 wherein said
15   terminal ends of said transmitting and receiving
optical fibres are convex in shape.

28.   The sensor of claim 18 wherein at least
one of said transmitting and receiving optical
fibres is a multimode optical fibre.

20   29.   The sensor of claim 18 wherein at least
one of said transmitting and receiving optical
fibres is a single mode optical fibre.

30.   The sensor of claim 18 wherein said at
least one reflective surface is flat.

25   31.   The sensor of claim 30 wherein said at
least one reflective surface is oriented at an
angle of between 25 and 35 degrees with respect to
longitudinal axes of said transmitting and
receiving optical fibres.

30   32.   The sensor of claim 18 wherein said at
least one reflective surface is disposed adjacent
the distal end of said tube.

5   33.   The sensor of claim 18 wherein said at
least one reflective surface is composed of
stainless steel.

       34.   The sensor of claim 18 wherein said at
10   least one reflective surface is concave.

       35.   The sensor of claim 26 wherein said at
least one reflective surface is concave.

       36.   The sensor of claim 27 wherein said at
least one reflective surface is concave.
15

       37.   The sensor of claim 34 wherein said
terminal ends of said transmitting and receiving
optical fibres are normal with respect to
longitudinal fibre axes of said transmitting and
20   receiving optical fibres.

       38.   A method for making remote fluid flow
measurements, said method comprising the steps of:
       transmitting an incident light beam through a
first optical fibre, said first optical fibre
25   disposed within a flexible tube;
       reflecting the incident light beam emitted
from a terminal end of the first optical fibre out
of an optical opening formed in a sidewall of the
tube into a measurement volume of the flow located
30   outside and alongside the tube, the reflected
light beam being scattered within the measurement
volume;
       receiving, through a terminal end of a second
optical fibre disposed within the tube, a portion
35   of the scattered light beam that is within a field
of view of the second optical fibre;

5   focusing the incident light beam to increase
   intensity of the light beam reflected into the
   flow; and
           focusing the field of view of the second
   optical fibre.

10   39.   The method of claim 38 wherein said
   incident light beam focusing step and said field
   of view focusing step include shaping the terminal
   ends of the first and second optical fibres.

        40.   The method of claim 38 wherein said
15   incident light beam focusing step and said field
   of view focusing step include shaping the
   reflective surface.

        41.   The method of claim 36 wherein said
   incident light beam focusing step and said field
20   of view focusing step include shaping the
   reflective surface.

1/6

DRAWINGS

FIG. 1

Fig 2

Fig 3
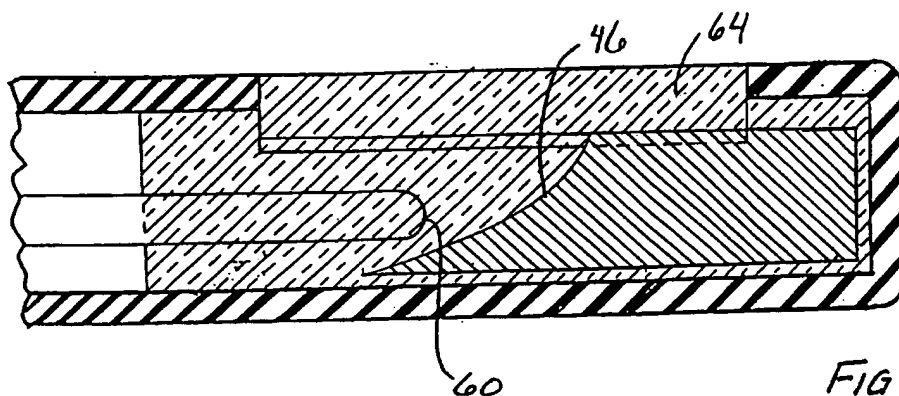
3/6

Fig 4

Fig 5

Fig 6

Fig 7
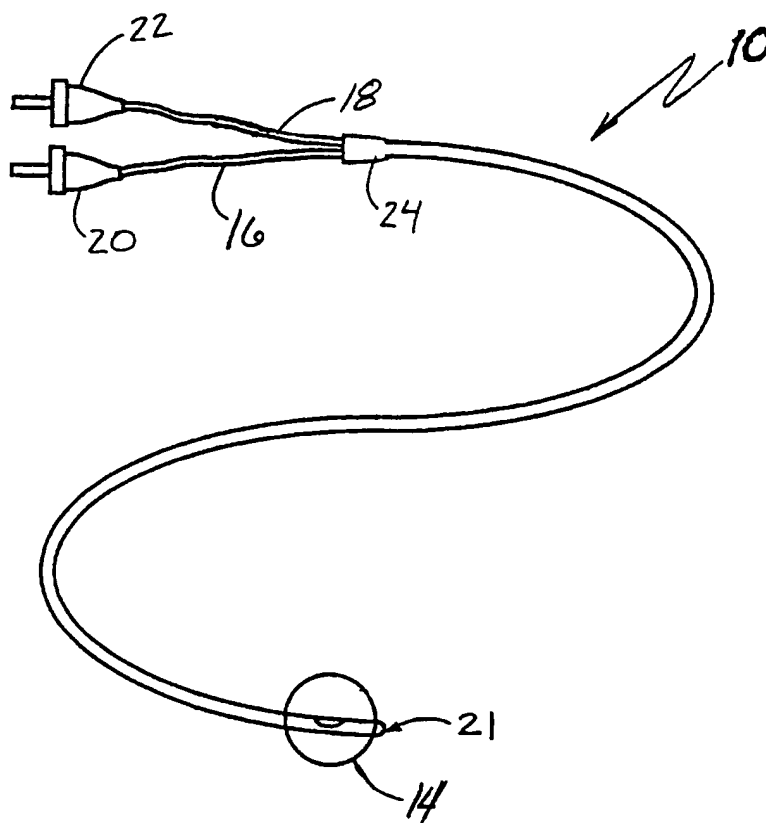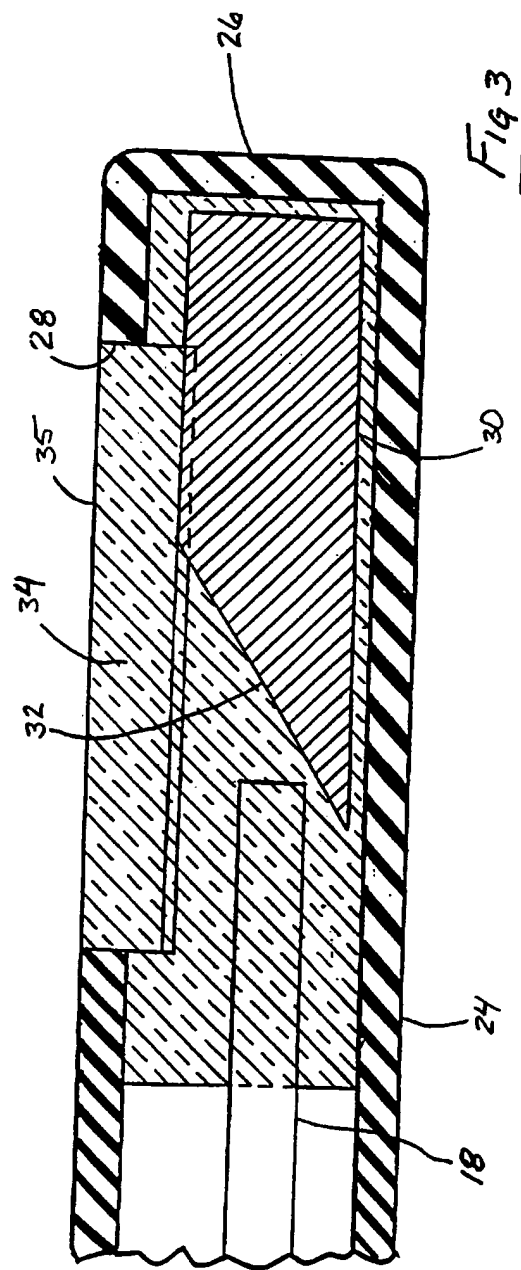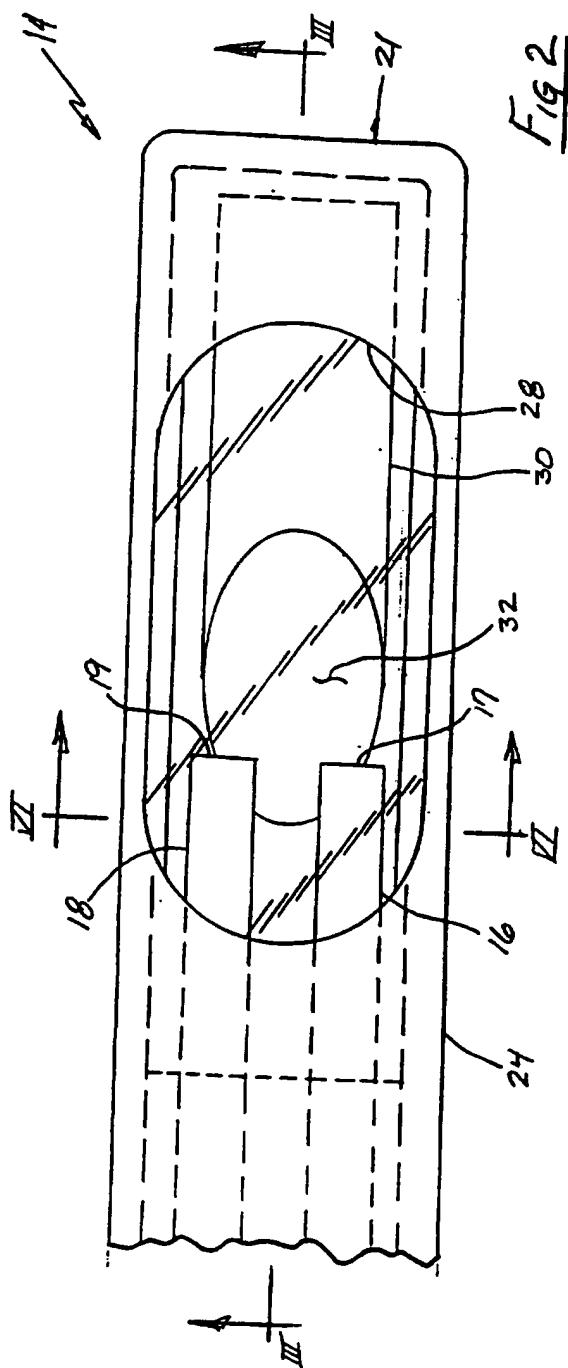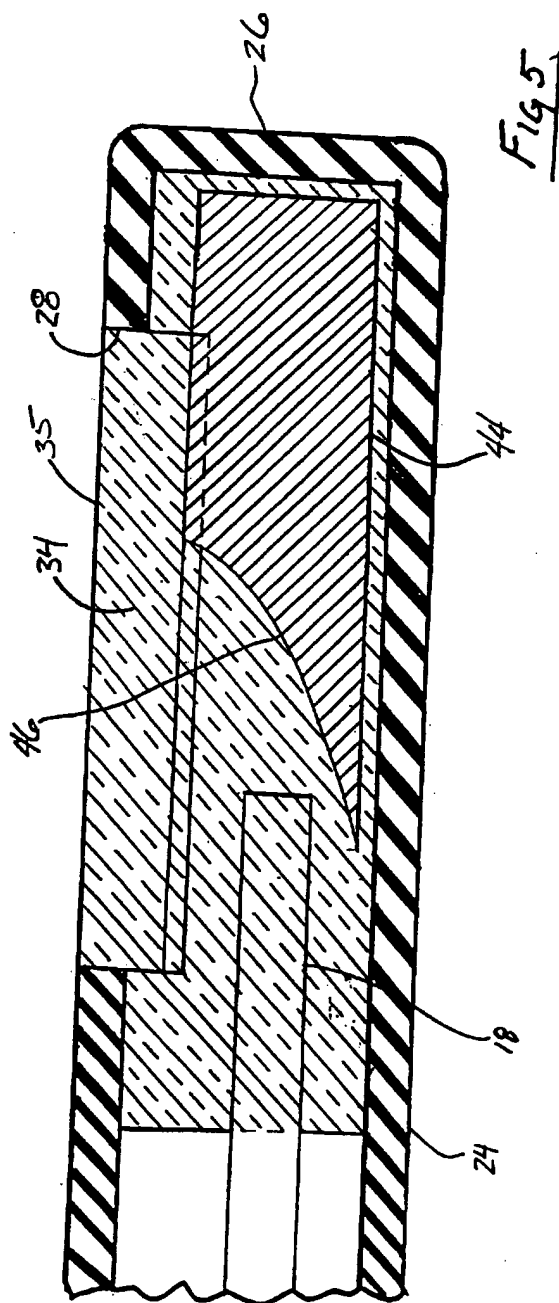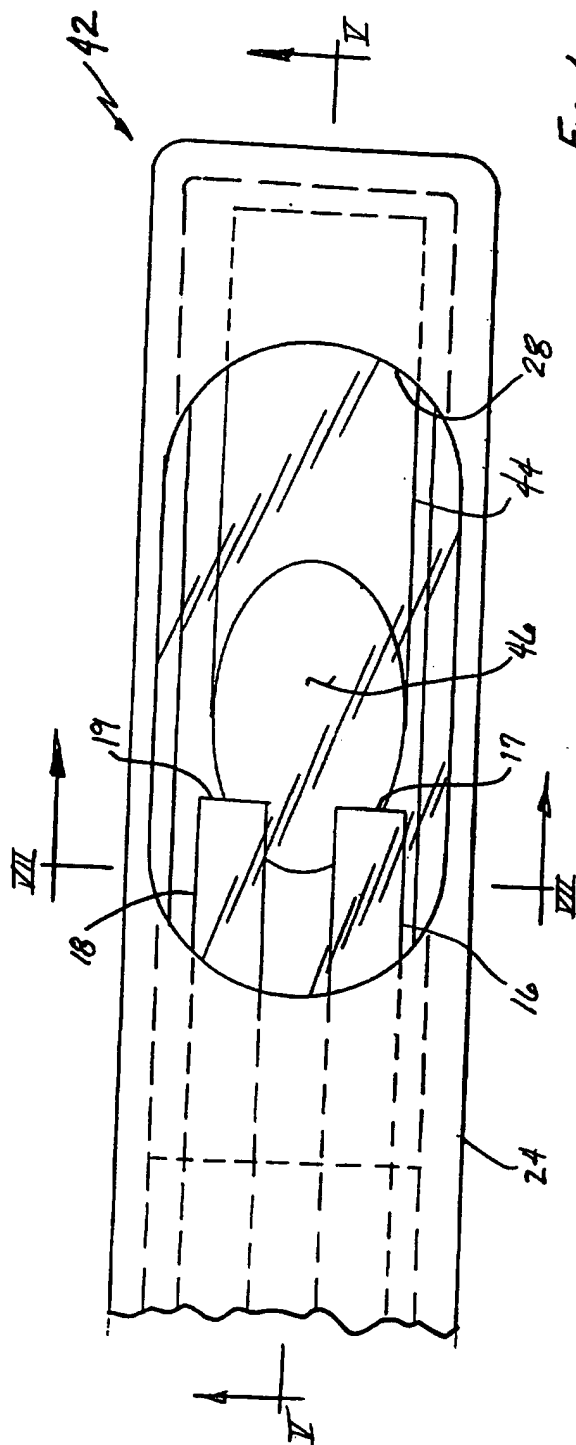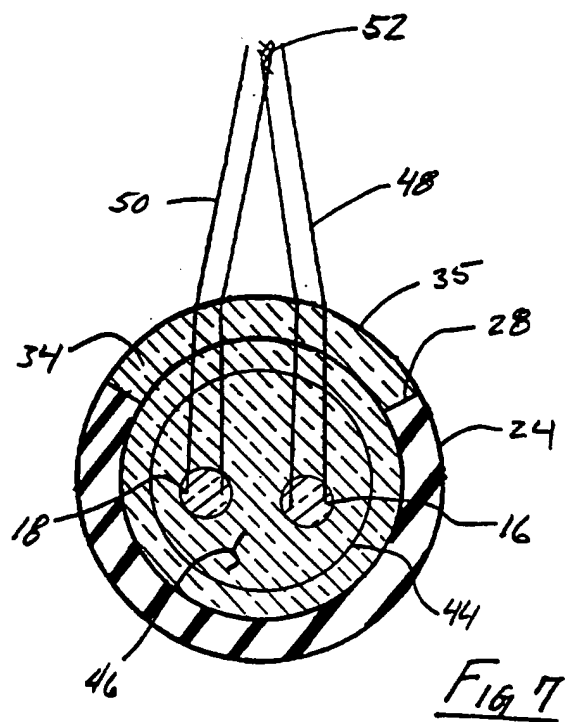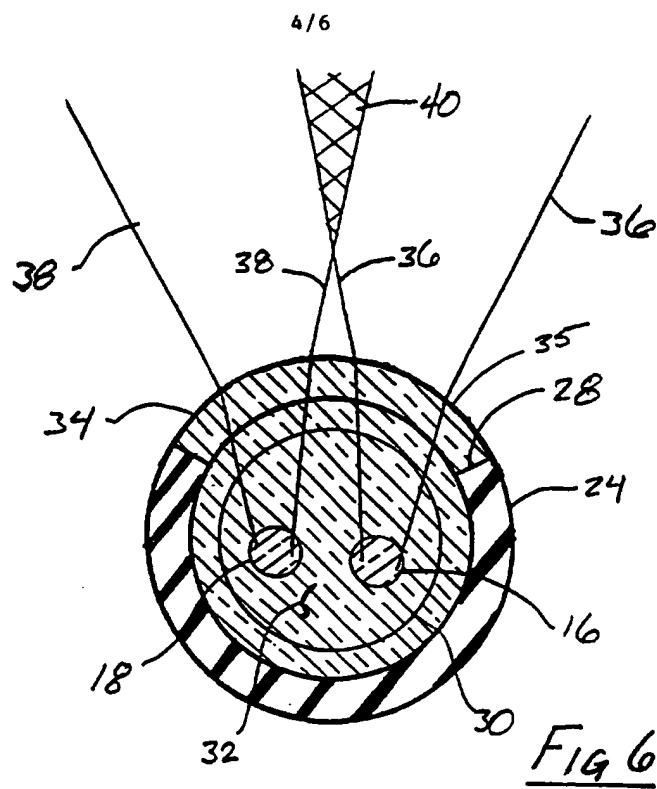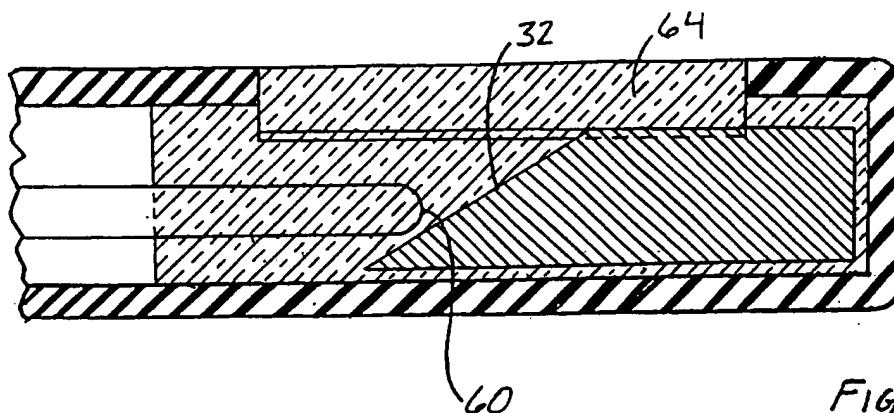
FIG 8A

FIG 8B
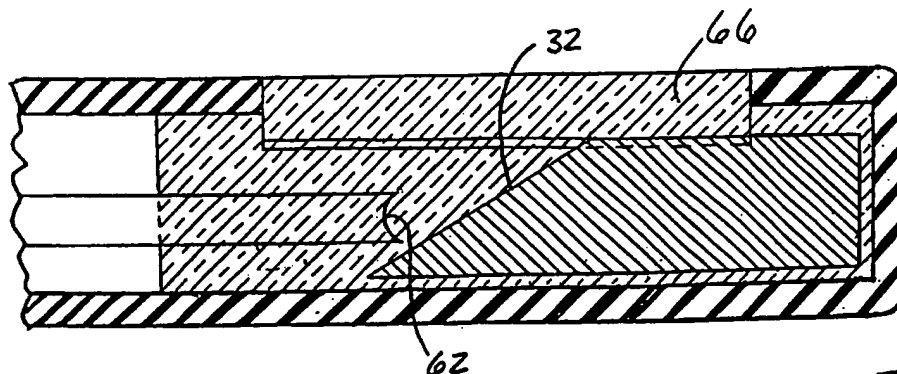
FIG 9A
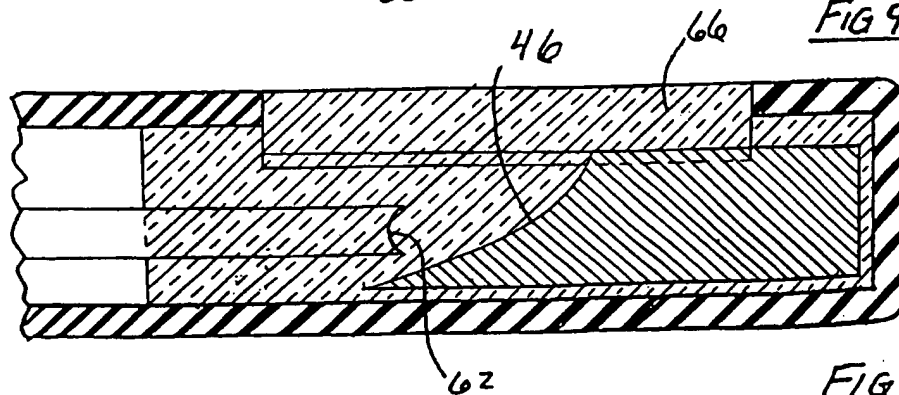
FIG 9B
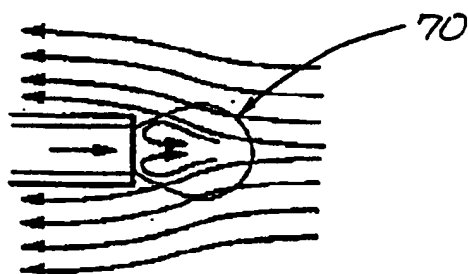
(PRIOR ART)

FIG 10

(PRIOR ART)   FIG 11

INTERNATIONAL SEARCH REPORT

A.	CLASSIFICATION OF SUBJECT MATTER

Int Cl⁶: G01F 1/66, 1/72, A61B 5/027, 5/0285

According to International Patent Classification (IPC) or to both national classification and IPC

B.	FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC: G01F 1/66, 1/72, A61B 5/02, 5/027, 5/0285

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C.	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 90/12537 A (RADI MEDICAL SYSTEMS AB) 1 November 1990 See Abstract and Fig 2.	1,2,4,6,18-21,30-32,38
Y	US 3674013 A (POLANYI) 4 July 1972 See Whole document	1,18,38
A	WO 95/19138 A (PACESETTER AB) 20 July 1995 See Abstract, Fig 6 and page 10	1,18,38

☐ Further documents are listed in the continuation of Box C   ☒ See patent family annex

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 29 February 1996	Date of mailing of the international search report 11th March 1996
Name and mailing address of the ISA/AU AUSTRALIAN INDUSTRIAL PROPERTY ORGANISATION PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No.: (06) 285 3929	Authorized officer S. Clark Telephone No.: (06) 283 2164

Form PCT/ISA/210 (second sheet) (July 1992) copkod

INTERNATIONAL SEARCH REPORT

C (Continuation)	DOCUMENTS CONSIDERED TO BE RELEVANT	
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Patent Abstracts of Japan, P-596, page 160 JP 62-38335 A (NIPPON KAGAKU KOGYO K.K.) 19 February 1987 See Abstract	1,18,38

INTERNATIONAL SEARCH REPORT
Information on patent family members

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member						
WO	9012537	SE	8901358					
US	3674013	CA	943834	DE	2132864	FR	2107329	
		GB	1345375	IL	37185	NL	7110850	

END OF ANNEX